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## THE SIGNIFICANCE OF THE HUMAN HAND IN THE EVOLUTION OF MIND.

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The human hand has long been an object of curious inquiry in connection with the study of character. The individual differences which it presents are many and striking. They affect the elements of color, venation, texture of skin, plumpness, size and general shapeliness. Variations in these factors give rise to a series of recognizable types which are popularly connected with special aptitudes and intellectual temperaments. Shapely hands, having a fine skin and tapering fingers, are the mark of an artistic nature; the broad hand, with firmly knit palm and short fingers, is characteristic of the man of affairs; the large-knuckled hand, with fingers set well apart and spatulous tipped, is the sign-manual of inventiveness and the philosophical bent. So close is the relation to human character and destiny which the conformation of the hand is supposed to bear that, like the shape of the head and the course of the stars in heaven, the interpretation of its signs has been made the subject of a so-called science and affords support to a numerous professional class.

The structure of the hand is complex and every feature is marked by well-defined and persistent peculiarities. The corrugations of the skin, constantly in process of destruction through the sloughing of the epidermis, are ceaselessly renewed in the very pattern and image of the original. The coarse-grained hand cannot be refined by any nicety of care, and that which is delicately moulded, though its shapeliness may be marred by the effects of heavy toil, bears to the end the hall-mark of its original beauty. The individuality of the hand, though more rarely noticed and studied, is no less characteristic than that of the human face; and like the latter possesses the capacity to preserve from generation to generation the traits which constitute family likenesses. Cavil as we may at the fine-drawn similitudes which have been made between the special features of the hand and the spiritual characteristics of its owner, and turn with disgust from the charlatany which pretends to read in the palm a prediction of human fortune and fate, we nevertheless cannot escape the belief that there is still an intimate connection between the features of the hand and the soul of man.

It is indeed but an instance of the general connection between the two parallel systems which we call bodily and mental, the specific correspondences of which are being established from day to day in our experience, and thus gives us knowledge of other human minds. To maintain such a significance in the form of the hand, therefore, is simply to assert the persistence of its characters in the individual, and their stability in heredity. The whole bodily system presents the same relations; our interest, however, lies not in broad differences which separate us from other organic types and characteristics which are common to the human race as a whole, but in the special variations of individuals which give to each his personal qualities and capacities.

For the bodily signs of these mental traits and conditions we look primarily to posture, action and other expressive changes. The correlation is between certain physical activities and mental states which we know directly only in our own consciousness. The diagnosis is thus made upon the basis of functional, not structural, characteristics. The conception of systematic co-ordination between mind and body is carried much farther when we include the permanent features of the body, as well as the reactions in which passion and purpose are expressed, as part of the physical index of the individual mind. Yet this we constantly do in greater or smaller measure. The ugliness of Socrates may not appear to us the paradox which it was to the Greeks, but we do, nevertheless, adopt an analogous point of view in our judgments, namely, that character is not only expressed in special acts, but also correlated with particular anatomical features. Either an ultimate connection exists which cannot be reduced to simpler terms, or the habitual activity which expresses a prevailing mental trait moulds the features, the posture and the disposition of the body as a whole to sympathetic forms, which even in the absence of any specific reaction we interpret in subjective terms.

Any individual stamp which the impressions and activities of a single life can thus impose upon the body is necessarily limited to its minor features and relations. Certain professional habits, unhealthy modes of life, and occupations which subject those who follow them to deforming or poisonous agents have well-defined diatheses which we read without hesitation. But these changes are practically confined to the muscular and fatty tissues and to dermal alterations due to interferences with the digestive and eliminative processes. The larger anatomical features of the body and its general external qualities remain practically unaffected by the fortunes of the individual, and reappear unchanged in his offspring.

But there is another point of view from which the whole

question of the significance of specific bodily features and organs in relation to the mental life may be regarded, namely, as the condition of mental development in the species. The body cannot be conceived as an organ of mind in any sense which separates the fortunes of the two, and makes of the mind an independent entity, as the user of an instrument is commonly independent, in nature and origin, of the implement which he employs. The mind can be called the instrument of the body as logically as the body that of the mind. The Aristotelian formulation is unsurpassable as a statement of their empirical relations. The mind is the system of functions connected with the body, regarded subjectively. It is not given as a determinate reality apart from the body, which is later brought into connection with the latter as a medium of expression. The mind is the mind of that particularly bodily type with which it is correlated; for the character and range of its experience are essentially related to the sensory and reactive mechanisms of the physical organism. The body is the mind's limiting and determining condition as well as its "agent;" and both the quality of its constituents and the level of its combinations change with every variation in the type of structure which supports it. The developmental histories of mind and body have followed parallel courses the incidents of which are inter-linked at every stage.

We commonly think of the central nervous system as the special physical mechanism with the elaboration of which the evolution of mind is primarily connected, yet it is to be questioned if this is not a mis-statement of the conditioning of mind upon its physical coefficient. The primary relation of the organism to its environment is that of a food consumer to its source of supply. Appropriative reaction is thus the basal activity with which all others are connected. But reaction is valuable only in so far as it is specific and intelligent, in the sense of being discriminative and selective. It must therefore be made under the guidance of sense. Discriminative sensibility makes possible the series of reactions upon which life depends. The number and quality of the objects upon which action is possible, as well as the range and character of the movements themselves, depend upon the nature and variety of the sense organs possessed by the organism. Sensation and movement are universally combined, in a unitary process which we describe as discriminative reaction, and this reciprocal relation between the organism and its environment was established long before the structures of the nervous system came into existence, and in manifold forms of life is maintained to-day in all its essential features in the absence of such a system.

The special purpose which the nervous processes serve is to

define and facilitate the reactions called forth by sensory stimuli. They consist of tracts of matter peculiarly sensitive to the propagation of impulses, which have differentiated from the primitive protoplasm and constitute the paths of habitual conduction between the point of stimulation and the mechanism of reaction. The development of such a system of paths is the necessary concomitant of the rise of localized reactions, and upon its presence depends that complex co-ordination by which any one of the whole series of sensory impressions to which the organism is susceptible can give rise to the same response, or a single stimulation arouse on different occasions any one of the whole series of reactions of which the animal is capable. But neither discriminative sensibility nor differential reaction can be regarded as a function peculiar to the nervous system, as both exist independently of its presence.

The possibility of the reflection of the world in consciousness is given in the differentiation of the sensory surfaces, and its realization depends upon the development of motor control. If it be justifiable at all to separate the constituents of a process so thoroughly unitary as the rise of the nervous system with its end organs of sense and movement, one should say that the evolution of intelligence depends upon the elaboration of the peripheral mechanisms rather than upon the central process, since in the former are given the materials and condition of development, while the function of the latter is to co-ordinate and transform the material thus given.

A special interest for the historical student of mind thus attaches not only to the evolutionary series in which the sensory apparatus of a given species takes form, but also to the system of mechanisms upon which its adaptive reactions depend. Among the instruments by which the activities of the mind are recorded and communicated none is of greater importance than the human hand. The function of expression centres supremely in the face, yet in a multitude of ways its message is supplemented by the action of the hands; while in all the more enduring records of intelligence the executive hand stands alone as the agent by which purpose is translated into plastic and tangible forms. The history of such a mechanism, at once so sensitive and so adaptive, is full of interest.

The structural evolution of the human hand has been outlined by the writer in another paper,<sup>1</sup> and the chief stages in its history may be summed up in a few words. This most highly adaptable member of the system of vertebrate limbs has successively fulfilled the functions of locomotion, support, suspension and manipulation. Having its rise in the lateral folds

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<sup>1</sup> Popular Science Monthly, September, 1904.

of the primitive fishes the fore limb received aquatic modifications represented in the bi-pinnate, unilateral and prong-fins, and on land underwent successive cleavages of the latter form resulting finally in the five-toed generalized form of mammalian limb. Descending through the plantigrade type of mammal the extremity of the fore limb, in common with the hind members, was first moulded to form a grasping organ, the system of digits in its final arrangement presenting the phenomenon of opposition, as do most arboreal types, like the perching birds and the chameleon. This structural differentiation, upon which so much of the subsequent fortune of its possessors depends, is essentially a modification of the foot, and is indeed the only adequate solution of the problem of support upon a rounded limb which can practically be conceived. Though in man its traces have largely disappeared from the foot, opposition took place in all four limbs before the erect or semi-erect posture was attained, in which alone this modification could receive the functional significance which raised its possessor so far beyond all other organic types in manipulative and constructive processes. The human hand is thus one of the most striking instances in nature of the operation of adaptation to one specific function in preparing an organ for a completely new series of activities.

The freeing of the hand for manipulative and constructive uses was the concomitant of skeletal and muscular development in the legs and the attainment of the erect posture, and together with the latter modifications prepared the way of the ape-man for a return to life upon the plain after his arboreal habitat. The new mode of life, while it presupposed the capacity for free and sustained movements of locomotion, called chiefly into play activities depending upon a high brain development and involving distinct mechanical constructiveness. For the primitive man was neither well armed, nor fleet of foot, nor possessed of natural weapons sufficient to maintain himself among his fierce competitors, and must have depended upon the distinctly human attributes of cunning and skill, the linking of resourceful brain with a highly developed manipulative organ.

For an explanation of the subsequent fortunes of man and the higher apes respectively we must turn to the divergent histories of their central nervous systems. "Henceforth," to quote the closing words of that article, "no important structural changes are to occur in the general features of the hand. Development is to take place chiefly through an increase in the facility and precision with which a variety of relatively simple movements are made, and the substitution, in ever increasing

grades of complexity, of mechanical instruments for the use of the hand itself as a manipulative and constructive agent."

Even in its immediate physical features, however, the hand must not be conceived to have suffered arrest at this point. It is indeed henceforth to be the servant of the brain. The value of its services is not to rest chiefly upon its strength, nor its endurance, nor even upon the swiftness of its movements, but upon its delicacy and adaptiveness as an organ of perception, and the promptness, accuracy and refinement of the movements made by it under perceptive direction. Nevertheless for the fulfillment of these new functions further structural evolution must take place in the hand. Cerebral development is met by peripheral modifications through which progress both in discriminative perception and differential reaction is made possible.

One of these necessary changes in the hand is its denudation of hair. The hairy coat of animals serves both as a protection and as a sense organ, the latter especially in cases where the hairs are long, stiff and sparse. The sensitiveness of the skin to stimulation applied through the hair-shaft can be tested in a moment by touching with the lightest possible contact the hairs on the back of the hand. But though delicate these responses are far from refined. The stimulation of the sense of touch in this manner makes known the proximity of a physical object but gives practically no information concerning its character. The presence of a hairy covering, therefore, stands absolutely in the way of the development of discriminative sensibility in the skin. In lower mammalian types as well as in man the law is exhibited; the sensitive surfaces of the mobile, exploring members of the body are everywhere freed from hair. A clear, naked skin is the prerequisite for the development of perception through sensations of contact.

Parallel with this process must go the specialization of the hand in the delicacy of its integumentary covering. No refined manipulation is possible with a hard and calloused skin, since it entails the lack of that responsiveness to subtle and varied stimulation upon which differential reaction finally depends. Such a change cannot have taken place in the limb so long as it was called upon to share in the function of quadrupedal locomotion, or was even employed constantly in grasping the rough surfaces of the trunk and branches of trees to support the body in climbing. The bare foot becomes leather-soled and insensitive, the hand employed in heavy labor grows callous and obtuse. No matter how adequate the supply of sensory nerves to such a limb it must remain useless to its possessor so long as a horny plate is spread between their terminals and the source of stimulation. A thin and pliable

skin, free from hairs and callosities, is thus the first of the series of refined modifications which the hand must present in its later evolution as a factor in the development of intelligence.

The most sensitive surfaces of the hand are the palmar regions, and within this general area especially the tips of the fingers. Sensitiveness there is four times as great as in the palm and ten times as great as on the back of the hand. As a condition of the development of such a sensitively tipped rod a degenerative process in the protective sheaths of the finger may be pointed out. When the terminations of the functional digits are shod with a horny covering, stimulations are conveyed to the peripheral nerves of touch only in the form of vibrations produced by the stroke of the hoof upon the earth or other solid object. The resistance of the surface, in such cases, combined with auditory and visual perceptions, furnishes information concerning certain practical aspects of the object with which the horny integument comes in contact, but no sense of touch in the ordinary acceptation of the term is involved.

When the modification of tissue takes the form of claws, as in the cat tribe and rodents generally, the tips of the digits can be brought into contact with objects only when the claws have first been embedded to their full extent, which occurs only when the limb is employed for other purposes than perception, for instance, in digging, climbing and seizing prey. In such animal types only the upper parts of the balls of the fingers and toes commonly come into contact with surrounding objects, and their tips, secluded and protected by the curve of the claws, remain undeveloped as sensory organs. The elimination of the claw took place relatively early in the evolution of the hand. In the lowest of the arboreal types it has already undergone a large amount of atrophy, two only of the digits in the middle lemurs being thus provided, and in the highest species one alone, the second toe. In the monkeys proper all the digits are already furnished with nails.

In addition to modifications of the epidermis and its appendages the adaptation of the hand to complex perceptive and manipulative functions involves certain changes in the structural relations of the limb. These may be summed up as consisting in the elongation of the digits and the relaxation of the system of muscles which bind the phalanges of the hand together; in other words, the hand must become slender, supple and flexibly articulated. The function of these modifications is chiefly to increase the opposability of the various constituents of the hand. The flexible articulation of the digits supplements the significance of the thumb by making possible a more perfect opposition between it and each of the fingers sep-

arately, and also allows of a secondary opposition among the digits themselves, less adequate indeed than the primary opposition of each of these to the thumb, but still of much importance in the exploration and manipulation of objects. The length and suppleness of the fingers permit also of a more complete opposition, by flexion, between the system of digits and the palm of the hand.

The significance of these various modifications in relation to the development of intelligence lies in the fact that the process of perception is elaborated point by point in dependence upon a system of motor reactions, the character of which determines the form and adequacy of one's intuition of the world. Pure sensory apprehension does not exist; since that interpretation of sensation through which the construction of the external world takes place in the mind can proceed only on the basis of specific movements called forth by the stimulus, in virtue of which the connections of various items of sensation with particular experiences of movement and resistance are one by one established through actual exploration and testing, until finally each calls to mind at once its proper associate, and the field of perception becomes a system of intelligible symbols which is instantly and correctly interpreted.

The perceptual world as it is presented in consciousness at any moment is thus a complex product which can have arisen only from the manifold and repeated experiences of many past moments in which the sensory content has been subjected to experimental variation and associated with specific forms of self-activity and its objective limitations. The more variously we have reacted upon the physical world the more full of meaning is the system of sensory stimulations which it affords, and the more extensive and exact our discrimination of its characteristics and relations. To a being sensorially perfect but incapable of reaction upon its environment the world in which we live must remain a pure phantasmagory of shifting sensations, a dream not of things but of impalpable subjective visions. The world becomes real to us only in so far as we are active in relation to it.

The features of the perceptual world which the senses of a given animal reveal to it must therefore in a very intimate fashion be dependent upon the character of the exploring and manipulative organs with which it is furnished, as well as upon the range of its special sensation. The mechanical limitations placed upon its reactions are at the same time conditions which determine the form and extent of the interpretation which it can put upon the sensory impressions which it receives. Without delicacy of the sense organ itself, that is, without those structural differentiations of its surfaces, in virtue of which it becomes capable of responding by distinct physio-

logical reactions to a multitude of minute modifications in the stimuli which act upon it, no differential reaction would of course be possible, and the discrimination of objects would fall to the ground from the lack of its fundamental basis; but were the structural development of the sense organ never so perfect, it would still be functionally useless as an organ of perception so long as the refined control of its movements remained in abeyance. One cannot imagine a clear perception of visual form, for example, to exist for an animal incapable of those co-ordinated eye-movements by which the contours of objects are traced and retraced with exactness and facility.

The function of muscular control in the perception of objects and space relations is not limited to the adjustments of the sense organ immediately concerned. A part of scarcely less significance in the interpretation of sensations of sight and hearing is played by the exploring movements of the limbs. Here again the mechanical limits placed upon the range and exactness of reaction condition the translation of visual and auditory sensations into perceptions of sight and hearing. Imagine any degree of perfection one pleases in the optic qualities of the eye in an animal like the horse, one is still utterly unable to conceive of any such a world dawning upon its intelligence as that which is presented through our own senses. The mere fact of the callous hoof and clumsy limb is an impassible barrier to an understanding of the subtle and varied impressions which we have supposed the eye to be capable of receiving. With a physiologically perfect organ of vision the innumerable refined modulations of form and surface of which vision gives us instant apprehension would remain, in the blank gaze of the brute, an unmeaning confusion of light and color. Without the illuminating touch of the mobile and sensitive hand the shapes of the solid objects about us would never have detached themselves from the general background of the field of vision and arranged themselves in the elaborately figured relief in which, at a single glance of the eye, they are revealed to us.

We have imagined the existence of an organ of vision physiologically well developed but inadequately provided with mechanisms of motor control. Such a supposition is, however, historically unwarrantable. Under the conception of evolution, whether arising from the inheritance of acquired characteristics or as a result of spontaneous variations, the perpetuation of a particular sensory modification depends upon the furtherance it affords to the system of useful reactions which the economy of life comprises. In other words its usefulness to the animal, and hence its conservation as a character of the species, is based upon the possibility of differential reac-

tion to the new sensorial qualities to which its appearance gives rise.

The rank of the various sensory mechanisms in the scale of importance as perceptive organs will be found intimately dependent upon the character of the apparatus of motor control with which they are severally provided. The physiological differentiation of a part of the sensitive body surface is but the first step in the elaboration of a sense organ. For any real development it must be followed by isolation from the general mass of the body and provision with such muscular appendages as will make possible independent local reaction and the variation at will of the relation of the sensory surface to its sources of stimulation. It is this facility and precision of control in the sensori-motor apparatus which lies at the basis of the common distinction between higher and lower senses, and gives such functional superiority to sight and touch over taste and smell. The development of bodily control in the form of organic adjustments and movements of exploration conditions every advance in the mechanism of sensory perception. They probably do not in any case produce those modifications in which the evolution of the senses consist, but their adequacy or insufficiency affords the selective environment which determines whether the new variations shall survive or perish. The muscular mechanisms of the body must thus undergo progressive development if useful modifications of the sensory areas are to be made efficacious in the evolution of intelligence.

In conclusion, it is necessary only to recall to mind that the process by which the hand becomes capable of fulfilling its exploring and interpretative functions does not consist solely in the elaboration of its architectural features, namely, in the acquisition of a pliable skin and flexible members. The incorporation of these modifications depends upon a parallel development of the system of sensory and motor nerves supplying the surfaces and articulations of the hand. Each of these sets of structures is indispensable. Without a full supply of sensory nerves the surfaces of the hand would be obtuse, and refined discrimination of the features of objects become impossible. The insensitive skin would interpose itself between the intelligence and its object like an impenetrable veil.

This, however, is but half the story concerning the part which the sensory nerves play in the acquisition of knowledge in regard to the world of objects and space relations. These perceptions depend also upon sensations deriving from the process of adjustment itself, and not due to the nature of the contact between the hand and the surface of the object explored. It is to these kinæsthetic sensations chiefly that we owe our

knowledge of the disposition and configuration of the objects about us. The limb must be sensitive within as well as without, in tendons and articulatory surfaces as well as throughout the external skin. Without this refined sense of position and movement the world might present to us a series of experiences of variously textured surfaces but scarcely one of objects and distances. By means of kinæsthetic sensation and its residues all the familiar adjustments of our bodies are made. To the exploring hand it is as a second visual sense by which the pathway of perception is illuminated and the space relations of objects recognized.

Kinæsthetic sensation arises of course in connection with passive as well as active movements, so that changes in the position of a limb brought about by purely external agencies are discriminated with a fair amount of exactness. Its characteristic function, however, appears in relation to voluntary reactions and their systematic co-ordination. The possibility of linking muscular reactions in a system of harmonious and purposeful movements depends upon the incoming stream of sensations which these reactions themselves arouse. The control of each successive movement which is to take place is conditioned upon the sensing of the adjustment which has just occurred. The moment this system of resident sensations is eliminated the reactions fall back into the primitive chaos which is exhibited in the impulsive movements of the infant, unless, indeed, they be directed in some secondary fashion, as by the sense of sight.

The development of a refined system of motor nerves employing a sensitive and flexible organ under the direction of kinæsthetic sensation forms thus the internal differentiation upon which the progressive adaptation of the hand in the service of intelligence depends. Since every intellectual advance is conditioned upon the possibility of realizing in concrete form those more elementary conceptions from which it proceeds, it is perhaps not too much to say that the hand, through which alone this embodiment of thought and purpose is mediated, is of all bodily members the most human and most noble; and that in its features and capabilities is symbolized all that man has achieved in his long upward march from the primeval ooze.